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WELDING OF NICKEL AND OTHER CONDUCTORS COMMONLY USED IN MODULAR ELECTRONICS ASSEMBLIES: AN ANNOTATED BIBLIOGRAPHY

SPECIAL BIBLIOGRAPHY
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Compiled by
CHARLIE M. PIERCE

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Lockheed

MISSILES & SPACE COMPANY
A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION
SUNNYVALE, CALIFORNIA

ABSTRACT

Nickel, in the form of wire and thin strips, is a commonly used material in modular electronics assemblies. The primary purpose of this bibliography is that of providing information on the physical properties and weldability of nickel. References are also included on intimately related topics such as welding techniques and practices, welding equipment, welding standards, and quality control. A section is also included on the application of welding to the fabrication of electronics circuitry.

The 124 references which are included have been grouped by subject topics and arranged according to the author. References which do not list authors are arranged according to a key word in the title. The period of coverage dates from 1950 to June 1962.

Search completed July 1962.

Availability notices and procurement instructions following the citations are direct quotations of such instructions appearing in the source material announcing that report. The compiler is well aware that many of these agencies' names, addresses and office codes will have changed; however, no attempt has been made to update each of these notices individually.

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Part I
THE PHYSICAL PROPERTIES OF NICKEL

1. Bokstein, S. Z., Kishkin, S. T., and Moroz, L. M.
Effect of metal composition and structure on grain boundary diffusion. In RADIO-ISOTOPES IN SCIENTIFIC ˋ ESEARCH v. 1, Pergamon Press, New York, 1958, p. 232–248.

Discusses boundary diffusion at high (up to 1350°C), and low temperatures. Information is included on the diffusion of Sn in Ni.

2. Field, W. G.
Ultra-high pressure physics. AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Paper no. 60-WA-331, 16 Dec 1960, 8p.

A discussion is included on the effect of crystal structure on the melting point, rigidity, and compressibility of Ni.

3. Friend, W. Z.
Nickel and high-nickel alloys. In SHORT COURSE ON PROCESS INDUSTRY CORROSION, PROCEEDINGS. National Assoc. of Corrosion Engineers, Houston 2, Tex., 1960, p. 99–117.

A discussion is presented on the corrosion resistance of Ni and its alloys.

4. Kralik, F.
Plasticity as a function of the latent heat of fusion, latent heat of evaporation and the sublimation temperature. HUTNICKE LISTY v. 14, p. 758–761, Sep 1959. (In Czech.)

Information is included on the correlation between the values of latent heats and the plastic properties of Ni.

5. Mackliet, C. A.
Diffusion of iron, cobalt, and nickel in single crystals of pure copper. PHYSICAL REVIEW v. 109, p. 1964– 1970, 15 Mar 1958.

Radioisotope techniques were used to determine diffusion rates under temperature conditions of 700 to 1075°C. Thirty-one references.

6. Mykura, H.
An unusual grain boundary diffusion effect in impure nickel. PHILOSOPHICAL MAGAZINE v. 4, p. 907–911, Aug 1959.

A discussion of the relationship between the formation of internal gas bubbles and the formation of ridges at the grain boundaries of Ni during thermal etching.

7. Pratt, E. M. and Cornwall, H. R.
Bibliography of nickel. U. S. GEOLOGICAL SURVEY BULLETIN 1019-k, 1958, 60p.

Part II
WELDING OF NICKEL AND ITS ALLOYS

8. Abaravich, V.
Cupro-nickel welded with aluminum bronze.
WELDING JOURNAL v. 37, p. 220–224,
Mar 1958.

Weld deposit cracking can be eliminated by using an inert-gas consumable-electrode process.

9. Abramovich, V. P.
Mechanical properties of welded and soldered
butt joints of copper and copper-nickel alloys.
SVAROCHNOE PROIZVODSTVO p. 31–33,
Feb 1959. (In Russian)

The quality of the metal surface determines the tensile strength of Cu and Cu-Ni alloys.

10. Bagryansky-Kuzmin, K. V. and Kassov, D. S.
Automatic submerged arc welding of pure nickel
with granulated flux. SVAROCHNOE PROIZVODSTVO
v. 1, p. 6–8, Nov 1959. (In Russian)

Suggests that non-acid fluxes should be used in the semi-automatic and automatic welding of Ni and Ni alloys. The recommendation that welding should be done with a Ni electrode and ceramic flux is presented.

11. Bagryanskii, K. V. et al.
Arc welding of nickel. KLUIMICHESKOE MASHINOSTROENIE p. 40–42, Sep – Oct 1961. (In Russian)

Information is presented on the submerged arc welding of NP-2 nickel to St. 3 steel. Data on the impact value, elongation, bend and tensile strengths of weldments is presented. The affects of C and Fe on the crack formation of weld metal is discussed. Preheating to temperatures of 200 - 250°C eliminates porosity.

12. Blanc, G. M. A., Colbus, J. and Keel, C. G.
Notes on the assessment of filler metals and fluxes. WELDING JOURNAL v. 40, p. 210s–222s, May 1961.

Sections are included on the surface tension of Cu-Ni-Zn filler metals and boric acid and borate fluxes. The relationship between the strength of the brazed joints, surface tensions, the viscosity, and the wetting power of filler metals and fluxes is described. The effects of various surface active substances on surface tensions and wetting powers is included.

13. Blumenstein, W.
Design for faster spotwelding. PRODUCT ENGINEERING v. 32, p. 76–80, 24 Apr 1961.

Stronger welds and faster production rates can be achieved by proper design considerations for welds and weld spacing. Recommendations are included for welding Ni and its alloys.

14. Brazing nickel and its alloys need proper methods, material. CANADIAN MACHINERY AND METALWORKING v. 72, p. 116, 138, Sep 1961.

A discussion of stress relief, mechanical, and chemical cleaning prior to brazing of Ni and Ni-base alloys is given. A description of heating methods, fluxes, and atmospheres for brazing with Ag-Cu-Zn-Cd alloys is presented.

15. Bredzs, N. and Schwartzbart, H.
Grain boundary penetration and base metal erosion in high-temperature brazing.
WELDING JOURNAL v. 41, p. 129s–144s, Mar 1962.

A section is included on the results of pad tests on pure Ni brazed with Fe-B, Fe-Si, Ni-B, Ni-Si, and Pd-B filler metals. A discussion of grain boundary penetration in terms of interfacial energy relationships is given.

16. Frolov, V. V.
Thermodiffusion processes in the base metal during welding. SVAROCHNOE PROIZVODSTVO, p. 1–5, Sep 1960. (In Russian)

A discussion is presented on the porosity in weldments caused by the diffusion of gasses in base metals caused by uneven heating. Information is included on the diffusion coefficient for Ni as a function of density, thermal capacity, heat conductivity, melting point and hydrogen content.

17. Hinde, J.
Developments in the welding of nickel and high nickel alloys in the chemical industry.
AUSTRALIAN INSTITUTE OF METALS JOURNAL v. 5, p. 254–263, Nov 1960.

A discussion of welding preparations; heat treatment requirements; topics on resistance, oxy-acetylene, argone, and metal arc welding; weld finish and weld quality.

18. Herrmann, H.
Welding of nickel and nickel alloys. GIESSEREI PRAXIS n. 17, p. 344–346, Sep 1958.
(In German)

A discussion is given on the physical properties of pure Ni and Ni alloys. Welding by electric arc, carbon arc, iner-gas-shielded, atomic hydrogen, and resistance are discussed.

19. Inglish, N. P. and Taylor, E. A.
Welding in the non-ferrous field. BRITISH WELDING JOURNAL v. 8, p. 419–436, Sep 1961.

A discussion is included on the developments in welding processes for Ni. Welding properties, characteristics, and applications of Ni is reviewed.

20. Jefferson, T. B.
The meaning of weldability. WELDING ENGINEER v. 43, p. 5--20, Mid-Jun 1958.

A section is included on the mechanical, chemical, and physical properties of Ni as related to weldability.

21. Kocher, R.
Nonferrous welding in the construction of pressure vessels. INDUSTRIE-ANZEIGER v. 81, p. 1613–1615, 11 Dec 1959. (In German)

Data is included on the arc welding of Ni and Ni alloys. Information on the tensile, impact, bend strength, and elongation of weldments is given. The effects of the sulfur content of grease and the presence of alloying elements on hot brittleness is touched upon.

22. Kocher, R.
Welding of nickel and nickel alloys. SCHWEISSTECHNIK v. 14, p. 111–113, Oct 1960. (In German)

Data is given on the welding of pure Ni and Ni alloys by protective gas welding and open arc welding with coated electrodes. The importance of preventing sulfur and oxygen contamination during welding is stressed.

23. Kuz'min, G. S. and Kassov, D. S.
The automatic submerged-arc welding of commercially pure nickel with a ceramic flux. WELDING PRODUCTION p. 17–23, Nov 1959.

24. Lloyd, D. C.
Low-temperature silver-brazed joints strong, easily made on almost any joint. CANADIAN MACHINERY AND METALWORKING v. 72, p. 88–89, 101, Sep 1961.

The use of Ag alloys in torch and furnace brazing of Ni is included. Mention is made of electronics and aircraft applications.

25. Perry, E. R.
Heat resistant brazing solders for alloys rich in Ni. JOURNAL de la SOUDURE v. 50, p. 171–176, 6 Jun 1960. (In French-German)

A brazing method is discussed for parts which are to be exposed to service temperatures of 600 - 800°C. The brazing is done at temperatures between 815 - 1250°C. With solders containing Pb. The solders exhibit good flowing and welding characteristics. The low metallurgical changes incurred in the base material is attributed to their use.

26. Resistance welding of nickel and high-nickel alloys. INCO TECHNICAL BULLETIN T33, Sep 1959, 34p.

Information is presented on spot, seam, flash, and projection welding. Resistance brazing of Ni to itself and other metals is included. The selection of proper welding processes, cleaning procedures, process variables and equipment, defects and their causes, testing, and inspection methods are discussed.

27. Schmid, A.
Application of tig welding to steels and copper and nickel alloys. BROWN BOVERI MITTEILUNGEN v. 48, p. 462–474, Aug – Sep 1961. (In German)

A review of the application of Tig welding techniques to Ni and Ni alloys. The preparation of seams and weld testing is discussed.

28. Patriarca, P. and Manly, W. D.
Bonding of cermet-valve components to metals.
WELDING JOURNAL v. 37, p. 249s–254s,
Jun 1958.

Information on techniques and procedures for brazing titanium carbide nickel to Ni without the use of brazing alloy.

29. Spencer, L. F.
Resistance welds will improve if you know your
metals and electrodes. WELDING ENGINEER
v. 43, p. 54, 56, 58, 59, Dec 1958.

Information is included on material standards for electrodes and weldability of Ni.

30. Welding of nickel and nickel alloys. TECHNICA
p. 1518–1520, 20 Dec 1957. (In German)

31. Welding of nickel and nickel alloys. TECHNICA
p. 31–36, 3 Jan 1958. (In German)

32. Welding of nickel and nickel alloys. INDUSTRIE
FRANCAISE, ACHATS et ENTRETIEN v. 9,
p. 243–248, Mar 1960. (In French)

A discussion of methods and shop practice.

33. Young, J. G.
Progress in the fusion welding of nonferrous
alloys. SHEET METAL INDUSTRIES v. 36,
p. 557–566, 576, Aug – Sep 1959.

Information is included on the equipment and processes for welding of Ni.

Part III

WELDING EQUIPMENT, TECHNIQUES, AND STANDARDS

34. Akulov, A. I.
Automation in production welding. BULLETIN OF THE NATIONAL LENDING LIBRARY FOR SCIENCE AND TECHNOLOGY TRANSLATIONS v. 3, p. 676–687, Aug 1961.

A summary of the proceedings of the All-Union (USSR) Conference on integrated mechanization and automation of production welding. Topics on gas arc welding, submerged arc welding, resistance welding, weld surface reinforcement, and gas flame processing are included.

35. Balder, T. C.
Influence of the peltier effect in resistance welding. PHILIPS TECHNICAL REVIEW v. 20, p. 188–192, Feb 1959.

Information is presented on the influence of current direction in the resistance welding of different metals together.

36. Bangs, S.
Hughes aircraft gets ready for ultrasonic welding. WELDING DESIGN & FABRICATION v. 35, p. 42–43, Mar 1962.

Sections are included on the welding of Dumet to Ni and Ni to Cu.

37. Capacitor discharge welding. WELDING AND METAL FABRICATION v. 28, p. 155–157, Apr 1960.

Information is given on the welding of thermocouple junctions of a wide range of materials and diameters. The welding apparatus and the variety of welds which can be made from similar and dissimilar thin materials is discussed.

38. Carl, W.
Influence of welding position and electrode diameter on economics of high-efficiency electrodes. OERLIKON SCHWEISSMITTEILUNGEN v. 18, p. 9–23, 1960. (In German)

39. Colbus, J.
Experimental analysis of the joining process in soldering. SCHWEISSEN und SCHNEIDEN v. 10, p. 50–54, Feb 1958. (In German)

A discussion of the mechanism of joining, temperature measurements in soldering, and tensile strength testing. The author feels that the best joints require a liquid layer between the solder and the parent metal. The minumum temperature at which effective joining occurs is dependent on the type of metal.

40. Diffusion bonding, brazing join copper parts. WELDING ENGINEER v. 46, p. 46, Feb 1961.

Information is presented on a new bonding technique in which a coating material on the metal surface diffuses into the contacts. An exposure to temperatures of 1700°F in a hydrogen or inert gas atmosphere produces strong bonds without interfaces.

41. Narrower, deeper electron-beam welds. METALWORKING PRODUCTION v. 105, p. 66, 8 Nov 1961.

A description is given of a welding process which can be applied to welding miniature workpieces and joints. A welding beam depth to width ratio of 20:1 can be achieved in Al and 10:1 in stainless steel. Welding is accomplished in vacuum chambers using accelerating voltages of 30 kv or less.

42. Sandia modifies electron beam welder to increase power input. WELDING DESIGN & FABRICATION v. 35, p. 62, Mar 1962.

A vacuum within a vacuum arrangement eliminates excessive splattering and melting of metal during welding. This arrangement protects the electron gun from damaging and power limiting arcs produced by gas induced pressure surges.

43. Engquist, R. D.
Metallurgy of resistance welding. In WELDED ELECTRONICS PACKAGING, PROCEEDINGS OF THE FIFTH SYMPOSIUM, Sunnyvale, Calif., 21 Aug 1961, 42p.

This paper consists of three basic parts: (1) a review of elementary solid state physics, (2) presentation of a theoretical consideration of the resistance welding process, and (3) some practical examples relating theory to actual practice.

44. Faulkner, D. S.
Electrical resistance welding. WIRE INDUSTRY v. 25, p. 643–645, 647–648, Jul 1958.

A discussion is included on flash welding and butt-welding of small rods.

45. Fleischmann, W. L.
Welding qualification and component performance. MECHANICAL ENGINEERING v. 80, p. 82, Jul 1958.

A discussion is presented on weld metallurgical problems which are related to the zone affected by weld heat, weld deposit, joint design, and weld quality and its control. The interrelationship between component performance tests and weldability tests are outlined.

46. Hrbal, P.
Effect of a vibrating electrode on weld porosity. ZVARANIE v. 7, p. 169–171, Jun 1958. (In Czech.)

The use of a holder with invariable frequency does not decrease the porosity of the weld root welding in difficult positions.

47. Libsch, J. and Capolongo, P.
High-frequency induction brazing and soldering.
WELDING JOURNAL v. 38, p. 1059–1069,
Nov 1959.

A discussion on the composition and melting range of commonly used filler metals for induction soldering and brazing. Information is also included on fluxes, design of joints, and the equipment used.

48. Lincoln, J. F.
What should be done about welding standards.
In EIGHTH ANNUAL MIDWEST WELDING CONFERENCE. Chicago, Ill., 31 Jan – 1 Feb 1962.
(Sponsored by Chicago Section of AWS and Armour Research Foundation) Abstracted in ASM Rev. Metal Lit., v. 19, p. 24, Abs 336K, May 1962.

Information is included on the strength, stress, rigidity, ductility, and porosity of arc weldments. The application of testing methods is discussed.

49. Martz, L.
Welded butt joints with fine wires. REVIEW INSTR. v. 32, n. 8, p. 990–991, 1961.

A description of a welding technique using ceramic tubing as a mold to hold two dissimilar wires in contact while applying a local heat. The use of a flux is not necessary with reasonably clean wires.

50. Maslov, Yu. A.
Welding Industry, Ohio, Aerospace Technical Intelligence Center, Wright-Patterson Air Force Base. 31 Jan 1961, 133p. (Trans. no. MCL-805 of SVARSCHNOE PROIZVODSTVO, MOSCOW, pp. 1–53, 102–116, 169–202, 217–240, 1959).

The book contains data on manual arc and automatic welding electric resistance welding, gas welding and cutting. In it is described the history and the development of welding, the technology of welding steel, cast iron and non-ferrous metals, data on deformation and stresses during welding, electrowelding and gas-welding equipment, quality control of welding, as well as technical-economical bases of welding processes and safety measures during welding operations. The book appears to be a scientific aid on the Course of Welding for students of machine building plants and schools dealing in non-welding specialties, and can also serve as a textbook for foremen and technologists connected with industrial problems of welding.

51. Mattig, A.
Welding, brazing and soldering equipment and testing apparatus. VDI-ZEITSCHRIFT v. 101, p. 939–944, Jul 1959.

52. METALWORKING. PT. 1. MACHINING. OTS Selective Bibliography SB-460, 24p.

References are included on welding, soldering, and brazing. The references include research reports from the military services, Atomic Energy Commission, other government agencies, and foreign technical literature.

53. Nipples, E. F. et al
Electrode-tip life studies in series spot welding. WELDING JOURNAL v. 37, p. 241s–248s, Jun 1958.

Information is included on the effect of electrode geometry, composition, force, and current on the strength, diameter, and consistency of the weldment. Advantages of eliminating flashing during welding are discussed.

54. Owczarski, W. A.
Resistance autobrazing of wires to intermetallic thermoelectric materials. WELDING JOURNAL v. 40, p. 517–521, May 1961.

The process is characterized by self-melting of one base metal and wetting of the second base metal to complete the joint.

55. Perego, B. and Bellettati, G.
Study of welding times. RIVISTA di MECCANICA v. 11, p. 41–49, 29 Aug 1960. (In Italian)

Calculations are given for the total times required to execute joints in arc welding. The use of fusible electrodes, automatic submerged-arc welding, and oxy-acetylene welding is discussed.

56. Pierre, E. R.
Welding and the world of metals. MEMCO NEWS v. 13, p. 4–7, Feb – Mar 1962.

A review is presented on the history of welding metals. Methods discussed include: hammering, electroslag processes, fusion, spot, and arc welding. Welding equipment is also covered.

57. Radcliffe, S. V. and White, J. S.
Two simple methods for spot welding wires. J. SCIENTIFIC INSTRUMENTS v. 38, p. 363–4, Sep 1961.

A description is given of two simple pieces of spot welding equipment together with a discussion of their application to the welding of wires of different compositions and size.

58. Resistance welding control. MACHINERY LLOYD (OVERSEAS EDITION) v. 34, p. 38–41, 17 Feb 1962.

The application of ignitron valves and synchronous and nonsynchronous electronic timers for controlling heat, current, and slope and phase shift. Weld strength, output, and accuracy are discussed.

59. Shafer, O. B.
OPTIMUM SIZE RATIOS BETWEEN WIRES OF WELDED CONNECTIONS, Military Products Division, IBM Corporation, Owego, IBM Report 58-816-44, Oct 1958.

60. Spencer, L. F.
Spot welding procedures and design. Pt. 1,
WELDING ENGINEER v. 44, p. 35–39, Sep 1959.

The welding of ferrous and nonferrous metals is discussed. Data is included on electrode tip diameters and overlaps, edge distance, and spot weld spacing. Eighteen references are included.

61. New spot welding control makes its own ideal
welding condition. WELDING ENGINEER v. 45,
p. 42–44, Feb 1960.

Discussion of an automatic welding control developed by the Budd Co. The control automatically compensates for line voltage variations, applied forces, electrode wear, physical characteristics of the material, shunting and other conditions which would detract from the welding quality under conventional controls.

62. New spotwelding control. CANADIAN WELDER
v 51, p. 10–11, Feb 1960.

Welding efficiency is enhanced with a new electronic control. Good weld strength can be obtained on a wide range of metals.

63. AWS Standard welding symbols. METALWORKING
v. 15, p. 18–19, Jan 1959.

A chart of the more common symbols.

64. Standards for welding operations, equipment
and materials. SCHWEISSEN und SCHNEIDEN
v. 11, p. 139–142, Apr 1959. (In German)

65. Sterling, W. K.
Techniques of welding, soldering and die-
casting, TECHNICA p. 45, 17 Jan 1958,
(In German)

66. Thielsch, H.
Close control of preheating temperatures can prevent weld failures. WELDING DESIGN AND FABRICATION v. 34, p. 58-59, 62, Feb 1961.

Methods of preventing cracking, weld shrinkage, and weld distortion.

67. Van Peteghem, A.
Modern interpretation of several brazing phenomena, REVUEA de la SOUDURE-LASTIJDSCHRIFT v. 17, n. 2, p. 94-109, 1961. (In French)

A discussion is presented on the effects of time, temperature, distance, gas concentration, polarization, voltage, hydrogen content, and alloy homogeneity on the brazement. A section on Ni is included. The formation of oxide films, oxygen diffusion and corrossive effects in brazing are emphasized.

68. Vlahos, C. J.
What makes an effective soldered joint? MILL & FACTORY v. 70, p. 82-85, Apr 1962.

Criteria for evaluating and selecting solders, fluxes, and apparatus for particular applications. A section is included on the solderability of various metals, alloys, and coatings. The chemical, electrical, and mechanical properties of soldered joints is reviewed.

69. Vltavsky, M.
Increasing the productivity of resistance welding processes. ZVARANIE v. 9, p. 99-103, Apr 1960. (In Czech.)

A discussion of the efficiency of spot and seam welding processes. Topics include welding cycles, effects of electrode movements, intensity and duration of current flow, applied pressure, and welding and heating times.

70. Welding wires, rods, and electrodes.
ALUMINIUM v. 35, p. 477–479, Aug 1959.
(In German)

A discussion on standards and classifications.

71. WELDING, OTS Selective Bibliography SB-402,
Mar 1960, 14p.

Covers welding techniques, equipment, metals and alloys and methods of evaluating weldments.

72. Weldability of metals rated by process. MATERIALS IN DESIGN ENGINEERING v. 52, p. 149,
Aug 1960.

Information is included on arc, resistance, and thermit welding and brazing of ferrous and nonferrous metals.

73. WELDING MACHINE AND WELDING PROCESS CAPABILITY STUDY, Industrial Components Division, Raytheon Company, Bedford, Massachusetts,
Raytheon Rept. Nov 1960.

74. Eight experts pinpoint welding mistakes.
STEEL v. 149, p. 70–75, 23 Oct 1961.

Methods of improving the efficiency of welding include the use of properly designed equipment and the use of the proper materials. Overwelding is a frequent indication of poor welding technique.

75. Williams, D. D.
Theory and practice of spot welding. INGENIERIA INDUSTRIA v. 27, p. 131–134, 136, Oct 1960. (In Spanish)

A description of the types and composition of electrodes, welding resistance, and the contact surface areas as they relate to the spote diameter.

76. Wodara, J. and Wendler, H. D.
Condenser discharge welding. Ohio, Aerospace Technical Intelligence Center, Wright-Patterson Air Force Base. 9 Oct 1961, 9p. (Trans. no MCL-1396 of SCHWEISSTECHNIK v. 5, p. 203–205, 1961)

The differences between a condenser-impulse discharge welding and a condenser-impulse welding was described and a short consideration of available condenser-impulse welding machines was given. By the use of the FPK-O welding unit, the control units FPK-1a and FPK-1B were developed on the basis of the principle of condenser discharge. These units are interchangeable with the electronic control unit of the spot welder FWO5.

Part IV
SURFACE CONTAMINATION AND DECONTAMINATION

77. Kerstetter, D. R.
Carbon as an indicator of gas content in metallic tube components. In CLEANING OF ELECTRONIC DEVICE COMPONENTS AND MATERIALS, PROCEEDINGS OF THE SYMPOSIUM. Philadelphia. American Society for Testing Materials, STP no. 246, 1958, p. 94 – 100.

A discussion is included on the relationship between the carbon content and gas removal from Ni.

78. Klemperer, D. F. and Stone, F. S.
Heats of absorption on evaporated nickel films. ROYAL SOCIETY, PROCEEDINGS v. 243, p. 375 –399, 14 Jan 1958.

Information on the absorption of oxygen, hydrogen, and carbon monoxide on different Ni preparations is presented. The heats of absorption have been determined at room temperature. Twenty-eight references.

79. Lichtman, D.
Hydrogen absorption by tube parts due to various processing procedures. In CLEANING OF ELECTRONIC DEVICE COMPONENTS AND MATERIALS, PROCEEDINGS OF THE SYMPOSIUM, Philadelphia. American Society for Testing Materials, STP no. 246, 1958, p. 120–128.

A discussion is included on the effect of wet and dry hydrogen firing, hydrogen brazing, and baking conditions on the gas content of Ni.

80. Matsuda, A.
Sorption of hydrogen by nickel wire.
RESEARCH INSTITUTE FOR CATALYSIS, JOURNAL v. 5, p. 71–86, Nov 1957.

81. Tummers, G. E.
Welding of cupronickel tubing to a steel plate for use in high-pressure pre-heaters.
LASTECHNIEK v. 27, p. 1–3, Jan 1961.
(In Dutch)

Information is included on the elimination of S, P, C, H, and O absorption by properly cleaning the surfaces and working with dry electrodes.

82. Westphal, P.
Metal cleaning as physico-chemical problem.
METALLWAREN-INDUSTRIE und GALVANO-TECHNIK v. 49, p. 312–320, Aug 1958. (In German)

A discussion of effectiveness of various techniques and agents used in cleaning metal surfaces.

Part V
WELDING OF ELECTRICAL CONTACTS

83. Allen R., Clark, C., and Hayes, W.
DEVELOPMENT PROGRAM FOR MODULAR INTERCONNECTIONS FOR MICRO-ASSEMBLIES; Quarterly progress report no. 2, 30 Sep – 30 Dec 1960. United Aircraft Corp., Hamilton Standard Div. HSER-2303, 40p. ASTIA AD-252 020.

A 6-position fixture was made for welding wafers at one setup. A mold was made to pot wafers in stacks of four. A fixture for welding riser wires to the stacked wafers on a 25-mil grid was constructed. Fixtures for the vibration test and for resistance measurements and pull testing were built. Over 200 riser wires were electron beam welded to metallized alumina wafers to optimize machine parameters and establish testing methods. A technique for continuous-seam electron beam welding of each joint area was developed. Pull tests were made with both wires in tensile. Other tests were made with the weld nugget in shear. The shear method is shown to be a more reliable procedure. The electrical resistance of all welded joints was measured. A dc resistance method was used and all visually acceptable welds had a measured resistance within the requirement of SCL-7553.

84. Armstrong, L. D.
ADOPTION OF WELDED ELECTRONIC CIRCUITS FOR MISSILE AND SPACE VEHICLES, (Presented to Fourth Symposium on Welded Electronic Packaging, Airborne Instruments Laboratory, Melville, Long Island, New York.) Space Technology Labs., Los Angeles, Calif. Rept. no. STL/TR-60-0000-09178, 24 Mar 1961, 60p. (Contract AF 04(647)619).

The results of an investigation of welded electronic circuits for application to ballistic missiles and space vehicles are presented. Adaptation of welding to electronic circuits, development of welding process control, and circuit packaging design are discussed. Actual fabrication methods and practices are also discussed. Included is an evaluation of the basic technique, which indicates that a substantial improvement in reliability as well as considerable reduction in volume and weight can be achieved at no increase in cost.

85. Automatic resistance welding; the only way to make telephone relay contacts at a one-second clip. WELDING DESIGN & FABRICATION v. 34, p. 30–31, Jul 1961.

A discussion is presented on automatic relay spring processing machines. These machines are used to weld Ag contacts to flat Ni-Ag springs.

86. Boron, P. E. Assembling circuitry board for airborne computers. ASSEMBLY & FASTENER ENGINEERING v. 4, p. 31–36, Apr 1961.

The processes of dip soldering, microwelding, and adhesive bonding are discussed along with design features.

87. Buckman, W. D. HEAT DISSIPATION THROUGH DIODE LEAD WIRES UNDER STEADY-STATE CONDITIONS, Aerospace Corp., El Segundo, Calif., Rept. no. TDR-930(2121)TN-1) Oct 1961, 20p. (Contract AF 04(647)930).

Results of an investigation of the capabilities of wire leads to function as heat dissipating media are presented. Experimental work related to this project has confirmed that leads may serve as heat sinks to an extent greater than has generally been recognized, and has also served as a basis for derivation of the theoretical relationships which define the significant parameters involved. The experiments were conducted to generally determine the effects of varying wire lead materials, lengths, and diameters under both radiative and convective ambient conditions. The mathematical relationships which have been obtained provide quantitative methods for predicting the effect and behavior of component-generated heat on performance, and will permit better correlation between component wattage ratings as stated by the manufacturer and noted by the user.

88. Bullard, R. L. et al.
PLANAR INTEGRATION OF THIN FILM FUNCTIONAL CIRCUIT UNITS; Quarterly rept. no. 1, 1 May – 30 Nov 1961, 59p. Command Control Center, Federal Systems Div., Kingston, N. Y. (Contract DA 36-039-sc-87246; Proj. 3G26-14-001.)

A discussion of soldering and packaging is included.

89. Dembicka-Jellonkowa, St.
Welding of conducting electrodes to this metallic films. J. SCIENTIFIC INSTRUMENTS v.38, p. 2–62, Feb 1961.

Brief description of the capacitive discharge method of welding chromiumfilms with thicknesses of about 80 to 1000A.

90. Dunkel, W. E.
RELIABLE WELDED CONNECTIONS, Airborne Computer Laboratories, IBM Corporation, Owego, New York, Report 518-D-006, 15 Nov 1957.

91. Chernikoff, L. and Staller, J.
Circuits and packaging methods in an airborne digital computer. In AEROSPACE ELECTRONICS, PROCEEDINGS OF THE NATIONAL CONFERENCE ON, Dayton, Ohio, 8–10 May 1961. (Sponsored by: IRE, Dayton Section) IRE, 1961, p. 451–59.

Spot welding was used in the final equipment to form densely packed 3-dimensional elements containing approximately 50 components each. Welded wire interconnections are used to accomodate the large number of connections between elements, thus permitting ground planes and the necessary shielding. These welded interconnections

are all contained in a solid interconnection block with all connections made internally. A unique pin-to-pin wire wrap is used for the final marriage between the circuit elements and the solid interconnection block. Major sections of the back wiring are interconnected by the same pin-to-pin wire wrap technique.

92. Dow, J. R. and Messner, E. J.
Welding for smaller, sturdier electronic packages. SPACE/AERONAUTICS v. 36, p. 131, 133, 135, Oct 1961.

High-resistance spot-welding of "cordwood"-stacked components is one of the newest joining techniques for small and reliable electronic packages. Cordwood-stacking of components is feasible because successive welds do not loosen those previously made. It also requires only very short component leads, since the low average heat involved in resistance-welding largely eliminates thermal damage to components. Weld-packing furthermore provides high stiffness-weight ratios, and subsequent embedding in plastic provides more than adequate module strength. Since there are as yet no generally proven techniques for weld-packing, lead materials and electrode characterisitcs must be carefully considered and detailed records must be kept to provide production standards. Extensive checks of weld quality are also required.

93. Eckhart, J. M. and Lyon, R. F.
A practical approach to reliability in welded circuits. In WELDED ELECTRONICS PACKAGING, PROCEEDINGS OF THE FIFTH SYMPOSIUM, Sunnyvale, Calif., 21 Aug 1961.

The first section of this paper describes a system of techniques and controls whose end product is a reliable welded connection. The second section describes one nondestructive production weld testing device.

94. Gilman, B. W.
Welding miniature electronic components. WESTERN MACHINERY AND STEEL WORLD v. 51, p. 72–74, Apr 1960.

A discussion of welding units with miniature working parts for welding electrical components. To maintain exact tolerances of the components the factors of heat, pressure, current, and cleanliness are stressed.

95. Gray, P. J., Steigerwald, R., and James, P. N.
High-density electronic packaging-resistance welding. ELECTRONIC DESIGN v. 9, p. 44–47, 24 May 1961.

Resistance spot welding, used throughout the HDEP program, requires close control of process parameters and special lead materials. The techniques developed for reliable welds are outlined.

96. Grossi, O
Applications of resistance welding. MACCHINE v. 12, p. 1057–1069, Nov 1957. (In Italian)

A section is included on welding electrical equipment.

97. Heindl, J. C., Alberts, J. N., and Brock, B. D.
Metallurgical considerations in resistance welding electronic component leads. In WELDED ELECTRONICS PACKAGING, PROCEEDINGS OF THE FIFTH SYMPOSIUM, Sunnyvale, Calif., 21 Aug 1961, 30p.

Discusses the metallurgy of the metals commonly used for electronic component leads and the problems involved in resistance welding of them. Process variables are outlined, the metallurgy of the weld joint is discussed and the effects of coatings on the lead materials is discussed.

98. Heslin, C. J.
The reliable weld. In WELDED ELECTRONICS PACKAGING, PROCEEDINGS OF THE FIFTH SYMPOSIUM, Sunnyvale, Calif., 21 Aug 1961, 29p.

An examination of ways to improve the reliability of welded electronic modules.

99. Homstead, R. H.
DEVELOPMENT PROGRAM FOR MODULAR INTERCONNECTIONS FOR MICRO-ASSEMBLIES; (Final progress report, Jan – Apr 1961. United Aircraft Corp., Hamilton Standard Div., Windsor Locks, Conn., Apr 1961, 101p. (Contract DA 36-039-sc-85347,) ASTIA AD-260 992.

The development of a technique for fabricating reliable, welded, electronic micro-assembly connections with a termination density up to 1600 junctions per square inch resulted in electronic beam welding using the Hamilton-Zeiss electron beam machine. This is a statistically predictable, exceptionally reliable joining process. The process has a capability of fabricating 1600 terminations per square inch in a system configuration required in the Signal Corps Micro Module Program.

100. Homstead, R. H.
MODULAR INTERCONNECTIONS FOR MICRO-ASSEMBLIES; (Quarterly progress rept. no. 2, 1 Sep – 30 Nov 1961.) United Aircraft Corp., Hamilton Standard Div., Windsor Locks, Conn., 30 Nov 1961, 24p. Rept. no 5, HSER 2475, (Contract DA 36-039-sc-87301; Proj. 3A99-15-002). ASTIA AD-272 914.

Research continued on the development program for modular interconnections. The alumina wafers received were found to be out of square approximately 1 degree. The glass substrates were square within the required limits. Three approaches were tried to establish electron beam machining techniques to provide discrete terminal areas at selected points along the metallized edge of a substrate wafer: cutting of nickel plated wafers; cutting fired moly-manganese; cutting unfired moly-manganese. The unfired was the easiest to cut; the fired was good; and the nickel plated most difficult. The unfired moly-manganese was fired after cutting. A fired moly-manganese wafer was electroless copper-plated all over before cutting. Cutting was then done through both the copper and the moly-manganese. The wafer was coated with stop-off lacquers in the areas where plating was not desired and then nickel plated. The stop-off was removed and the excess copper etched off. This latter method looks very promising as a production method.

101. Hughes, W. L.
RESISTANCE WELDING AND BRAZING OF ELECTRONIC COMPUTER LEADS TO NICKEL CLAD COPPER WIRE. General Electric Company, Defense Electronics Division, Syracuse, New York. Report R59EMH35, Aug 1959, 31p.

102. Kerr, V. W. et al
DEVELOP WELD PROCESS-WELDED ELECTRONIC MODULE. Lockheed Aircraft Corp., Missiles and Space Div. Rept. no. MRI 270.06 May 1961, 84p.

The object of this investigation was to adapt the resistance welding process to the production of LMSD welded electronic assemblies and to develop the operating procedures and process contols needed.

103. Lefer, H.
Making minute parts faster is industry's big problem. WELDING DESIGN & FABRICATION v. 34, p. 76–78, Oct 1961.

The application of automatic welding equipment and precision welding processes to the fabrication of electronic components from tiny wires and whiskers is discussed. The tweezer weld system and capacitor discharge welding techniques are included.

104. Lewis, H. E.
Brazing missile and electronic components in dry hydrogen. Pt. 2. METAL PROGRESS v. 79, p. 94, Apr 1961.

Emphasis is placed on the control of atmospheric purity and temperature in brazing in dry hydrogen.

105. Mayo, G. W., Jr. and Hess, W. T.
Development of optimum resistance welding reliability through the study of welding parameters. In WELDED ELECTRONICS PACKAGING, PROCEEDINGS OF THE FIFTH SYMPOSIUM, Sunnyvale, Calif., 21 Aug 1961, and Massachusetts Institute of Technology. Instrumentation Lab. Rept. no. E-1053, 41p.

Discusses the importance of the reliability of welds in welded electronic module assemblies. Lead evaluation and standardization, weld strength measurements, static resistance measurements, and equipment calibration and non-destructive weld quality monitoring are among the topics discussed.

106. Better metal composites. MATERIALS IN DESIGN ENGINEERING v. 55, p. 15, 125, Feb 1962.

Two new techniques are described for obtaining a good Cu bond between the two components of a composite electrical contact.

107. Nickel alloys in instrumentation and electronics. NICKEL p. 1–11, Oct 1960. (In Italian)

Discusses the applications of high permeability, temperature compensating and constant elastic modulus alloys. Four references.

108. O'Connor, E. and Kerr, V. W.
ESTABLISH PRODUCTION CAPABILITY M. S. D. WELDED ELECTRONICS. Lockheed Missiles & Space Co., Rept. no. MRI 270.03 Nov 1961, 13p.

109. Plaskett, V. A.
HIGH DENSITY PACKAGING-WELDING.
Lockheed Aircraft Corp. Missiles and Space Division. Rept. no. MRI 243.01, Mar 1961, 56p.

This report provides the results of: weld equipment evaluation and qualification, metallurgical analysis of typical welds; evaluation of component lead materials; weld schedule development and certification; sample module assembly; and observance of changes in the state of the art.

110. Plaskett, V. A.
WELD SCHEDULE DEVELOPMENT AND EQUIPMENT EVALUATION. Lockheed Aircraft Corp. Missiles and Space Div. Rept. no. MRI 270.01, Apr 1961, 105p.

In the course of a broad investigation on welded electronics processes, a critical production need developed for the weld schedules required to join component lead materials to various interconnect materials.

111. Ramsa, A. and Engelmann, R.
STUDY OF MICROJUNCTION FORMATION TECHNOLOGY. Quarterly progress rept. no. 2, 1 Oct – 31 Dec 1961; CBS Labs., Stamford, Conn. Rept. no. 6, 1456-A, 8 Feb 1962, 34p. (Contract DA 36-039-sc-88900, continuation of Contract DA 36-039-sc-85337). ASTIA AD-273 616.

An investigation of the experimental method of determining the built-in voltage of abrupt pn junctions by capacitance vs. voltage measurements is given and possible errors are discussed. Preliminary results on the lithographic use of the electron beam for fabricating semiconductor devices are presented. A scaled down plasma torch for semiconductor applications is described. The report closes with a summary and discussion of the electron beam work performed under this contract.

113. Reynolds, J. H.
WELDABILITY OF ELECTRONIC COMPONENT LEAD MATERIALS. Lockheed Aircraft Corp. Missiles and Space Div. Rept. no. MRI 270.04, Jul 1961, 27p.

The conclusions of the research outlined here are as follows: Kovar, Dumet, Nickel, and Alloy 180 appear to be desirable materials for component leads. Gold flashing or plating improves weldability. Solder coated brass, solder coated copperweld, solder coated copper and low carbon stell-copper clad are acceptable materials for component leads. Gold and/or silver flashing improves weldability. Nickel-clad copper and bare copper wire are presently undesirable as component leads because of erratic welding response at all energy and pressure levels available on standard shop equipment.

114. Scholhammer, F. R.
Microelectronic joining techniques by electron beam processes. In WELDED ELECTRONICS PACKAGING, PROCEEDINGS OF THE FIFTH SYMPOSIUM, Sunnyvale, Calif., 21 Aug 1961; and United Aircraft Corp., Hamilton Standard Division Rept. no. TP 61-06, 37p.

This paper presents data which are believed to demonstrate that electron beam welding offers important advantages over other techniques in fabricating microminiaturized electronic circuitry of optimum density, weight, and reliability. The advantage of this technique, some of which are common to other welding techniques as well, are that electron beam welding provides a better electrical contact, improves reliability over soldered connections, reduces hazard of thermal damage to components, increases structural rigidity, and allows better process control.

115. Spot welding is the key to reliable miniaturized electronic parts. WELDING DESIGN AND FABRICATION v. 33, p. 34–35, Nov 1960.

A section is included on welding Ni to Ni and Ni to other metals.

116. The American Society for Testing Materials. ASTM STANDARDS, 1959 SUPPLEMENT PT. 2. NON-FERROUS METALS (SPECIFICATIONS), ELECTRONIC MATERIALS, Philadelphia 3, Pa., 1959, 267p.

Sections are included on the properties of Ni and Ni alloys.

117. WELDED ELECTRONICS DESIGN TECHNIQUES Lockheed Aircraft Corp. Missiles and Space Div., Rept. no. LMSD-704041, 22 Nov 1960.

This design manual is a compilation of acceptable design techniques for welded electronic modules to be produced by LMSD.

118. 3-D WELDING PROGRAM FOR ELECTRONIC CIRCUITS, Manufacturing Development Engineering, AC Spark Plug Division Report, 17 Nov 1959.

119. New "nugget" welding technique makes bow in development of miniature thermocouple. WESTERN METALWORKING v. 18, p. 36–37, Apr 1960.

Information is included on spot welding of Ni wires.

120. New bench-type welder for electronic applications. MODERN ASSEMBLY PRACTICE, p. 9, Jun 1960.

Describes a welder for fabricating delicate parts of thin-gage metals. Uses include the mass production of diode plate assemblies which require positive control of welding cycles.

121. RCA welds transistor parts in controlled atmosphere. ASSEMBLY & FASTENER ENGINEERING v. 4, p. 43–44, Apr 1961.

Describes the application of resistance welding in joining transistor covers to their base.

122. Magnaflash welding electrical contacts. FANSTEEL v. 1, no. 2, p. 2–3, 1961.

Information is given on a wide range of materials which can be welded by this process. Bonds of 99-100% of the total weldable areas can be obtained. This technique eliminates the need for special atmospheres and fluxes and the efficiency is such that the need for inspection can be reduced to a sampling procedure.

123. Semi-automatic welding of television components. AUSTRALASIAN MANUFACTURER v. 46, p. 71–72, 16 Sep 1961.

Information is presented on the equipment and the techniques used.

124. Wray, R. A. and Stech, H. G. Resistance welding sets new trend in module production, SPACE AERONAUTICS v. 35, p. 93, 96, 98–99, Apr 1961.

A method is described for producing joints wnich retain high strength at high temperatures. The joints are also resitant to the effects of shock and vibration. The welding of Ni is included.